Mars In Situ Tomography System (MISTS) Development for Characterizing the Stratigraphy of Polar Layered Deposits

Completed Technology Project (2018 - 2021)

Project Introduction

We propose to miniaturize an X-ray microcomputed tomography (microCT) system for in situ analysis of layered martian ice. The Micro In Situ Tomography System (MISTS) will provide the microstructural information we would seek from an ice core: millimeter scale stratigraphy of impurity layers and micron scale particle size, shape, and position. OBJECTIVE Mars has layered subsurface ice and polar layered deposits that contain a climate record relevant to studies of past habitability and climate science more generally. MicroCT provides non-destructive three-dimensional visualization and characterization of the internal features of multiphase materials with spatial resolution down to several microns. It has been used extensively in the study of depositional processes in sedimentary rock (e.g. Falvard and Paris, 2017) and more recently in ice (Obbard et al., 2009; Iverson et al., 2017). MicroCT can measure micron scale layer stratigraphy, particle size, shape, volume concentration, pore size, shape and distribution, all as a function of depth. The use of microCT to differentiate and identify depositional layers based on particle size and shape distribution in the ice has been demonstrated in the West Antarctic Ice Sheet (WAIS) core were used to identify the type and source of specific volcanic eruptions (Iverson et al., 2017). Application of the technique has been growing in part due to rapid advances in instrumentation technology and accessibility through commercially available benchtop systems. Typically a microCT system is located in a laboratory; however, in some situations it may be preferred (e.g. transport and curation of frozen samples) to bring the microCT to the samples. We propose to develop a miniaturized microCT system that can be used robotically to examine stratigraphy and sediment distribution in martian ice cores. TECHNICAL APPROACH The MISTS will be a two-step process. Immediately following collection, an ice core will be placed between source and detector and X-ray attenuation images collected. One of the challenges we foresee is the need to withdraw and image fractured cores. The ice coring drill will employ Honeybee Robotics' eccentric tubes core breakoff and retention technology, a metal bit with an internal breakoff and caching tube(s) made of an X-ray transparent polymer (Zancy, 2014). As the caching tube and core is drawn from the hole, it will pass though a surface mounted microCT system, which will image the sample in situ in the tube. Data (bitmap X-ray attenuation image files, vertical and azimuthal position, and X-ray source statistics) will be transferred to Earth, where tomographic images will be reconstructed. Tasks: 1. Determine optimal core diameter by weighing competing requirements such as sample size, tomographic spatial resolution, drilling and microCT power, and weight. 2. Specify X-ray source strength, integration time, detector resolution. 3. Identify microCT geometry, components (i.e. source and detector) and design. 4. Make design changes to current core breakoff and retention system, including the caching/analysis tube(s). 5. Build and test microCT system on caching tubes containing ice and sediment in the lab at cold temperatures. The proposed work is relevant to NASA PICASSO because we aim to design and develop a new miniaturized instrument to be used for in situ science in a planetary context. Under this

Image Not Available

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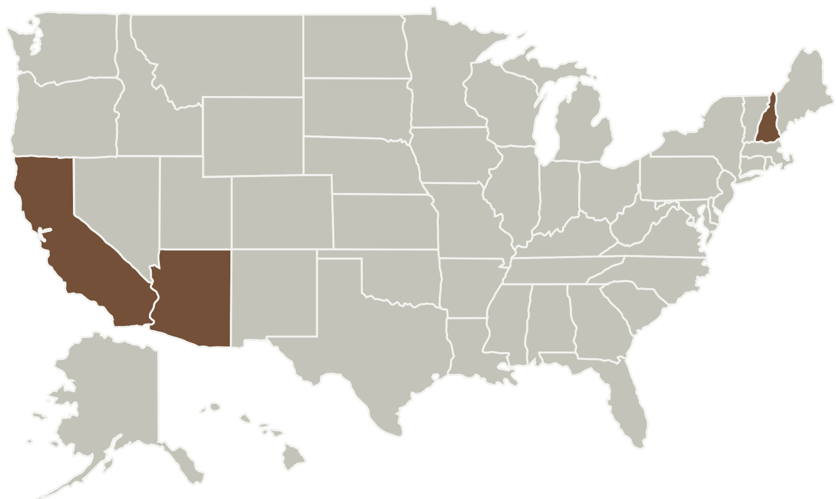
project, the proposed instrument will advance from TRL 2 to TRL 4. REFERENCES Chen, S., I. Baker (2010) Hydrological Processes, 24(14): 2034-2040 Committee on the Planetary Science Decadal Survey (2011) National Research Council. Falvard, S., R. Paris (2017) Sedimentology, 64(2): 453-477 Iverson et al. (2017) Nature Scientific Reports, 7: 11457. Lieb-Lappen et al. (2017) Cold Regions Science and Technology 138: 24-35 Obbard et al. (2009) Journal of Glaciology, 55(194): 1113-1115 Zacny et al. (2008) Astrobiology, 8(3). DOI: 10.1089/ast.2007.0179

Anticipated Benefits

Developing Instrument technology to improve measurements for future planetary science missions.

Primary U.S. Work Locations and Key Partners



Organizational Responsibility

Responsible Mission Directorate:

Science Mission Directorate (SMD)

Lead Organization:

Trustees of Dartmouth College

Responsible Program:

Planetary Instrument Concepts for the Advancement of Solar System Observations

Project Management

Program Director:

Carolyn R Mercer

Program Manager:

Haris Riris

Principal Investigator:

Rachel W Obbard

Co-Investigators:

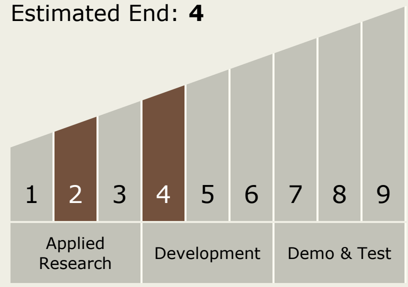
Shane Byrne
Christine M Bothe
Philippe C Sarrazin
Kris Zacny

Organizations Performing Work	Role	Type	Location
Trustees of Dartmouth College	Lead Organization	Academia	Hanover, New Hampshire
Dartmouth College	Supporting Organization	Academia	Hanover, New Hampshire
Honeybee Robotics, Ltd.	Supporting Organization	Industry	Pasadena, California
University of Arizona	Supporting Organization	Academia Hispanic Serving Institutions (HSI)	Tucson, Arizona

Primary U.S. Work Locations	
Arizona	California
New Hampshire	

Technology Maturity (TRL)

Start: **2**
Estimated End: **4**



Technology Areas

Primary:

- TX08 Sensors and Instruments
  - └ TX08.3 In-Situ Instruments and Sensors

Target Destination

Others Inside the Solar System